New Cloud Profiling Radar for Air Operations

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Introduction

In the late 1960s and early 1970s the U. S. Air Force used several AN/TPQ- 11 [Paulsen and Petrocchi, 1970] 35-GHz radars to aid airfield controllers. Unfortunately, the reliability of the high peak power magnetron transmitters used in those radars was low, and they were quickly decommissioned. An alternate technology, Traveling Wave Tube Amplifiers (TWTAS), can now be used to produce an equivalent level of average transmitted power at 35 GHz frequency. The Department of Energy (DOE), in collaboration with NOAA's Environmental Technology Laboratory (ETL), is now producing 35-GHz Doppler cloud-profiling radars based on TWTA technology for five global Cloud And Radiation Testbed (CART) sites, as part of the Atmospheric Radiation Measurement (ARM) program [Stokes and Schwartz, 1994]. The first of these highly-sensitive, vertically-pointing, unattended radars has been producing continuous data from the Southern Great Plains (SGP) CART site since November 12, 1996. The system monitors its own health, environmental conditions, and status of external power. It shuts down and reboots gracefully and automatically. It is also capable of automatic, routine calibration, and it manages data through both local archiving (backup) and transmission to an external data management and display system. The new radar is intended to gather data for 10-15 years in many different climatological regimes, to better understand the climatology and layering of clouds, and the role they play in radiative balance and climate change.

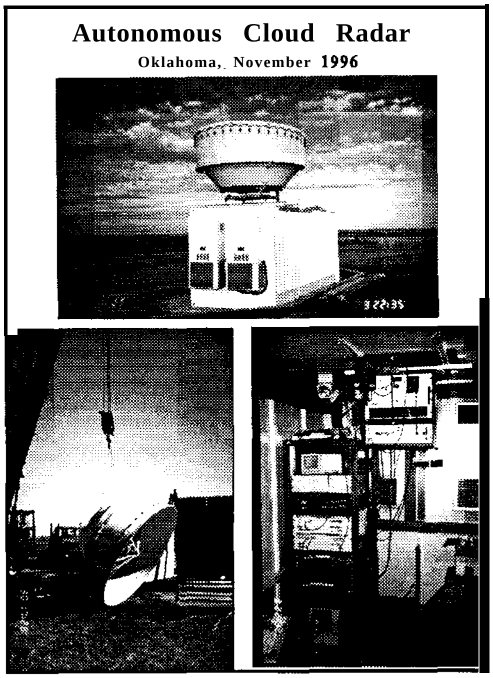

Fig., 1. Unattended 35-GHz cloud-profiling radar as installed in a seatainer at DOE's CART site near Lament, Oklahoma. Antenna is 3 m in diameter. Radar is mounted in a single rack and weighs about 140 kg.

It occurred to the authors that this system might be of interest to participants of the Battlespace Atmospherics Conference, for applications previously served by the AN/TPQ- 11 radar, namely air traffic control, both on land and at sea.

Description

Fig. 1 shows the seacontainer-housed radar at the SGP site near Lament, Oklahoma. DOE/ARM plans to house many other instruments in the same container, so the size of this facility is not necessarily representative of what is needed solely for the cloud radar. The radar itself, *sans* 3-m-diameter radomed antenna, weighs about 140 kg and is mounted in a single 2-m tall rack. For remote sites and overseas installations we plan to use 2-m diameter antennas that can

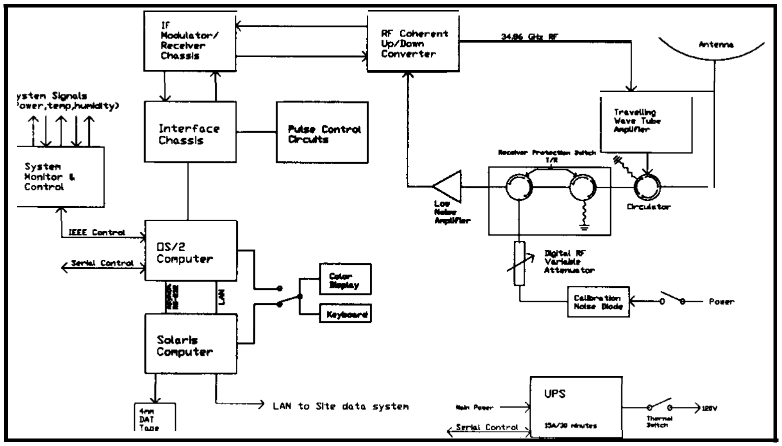

Fig. 2. Block diagram or radar. Note provisions for receiver protection and automatic calibration via noise diode and attenuators. Computer controls, health monitor-k and data system are not indicated.

Table 1
Operating Characteristics DOE/ETL Cloud Radar at SGP

Frequency	34.86 GHz (λ=8.66 mm, Ka-band)
Peak Transmitted Power	100W
Max. Duty Cycle	25%
Antenna Diameter/ On-Axis Gain	10 ft. / 57.3 dB
Beam Width	0.2 deg.

OPERATING MODE →	1	2	3	4
Inter-pulse Period (μs)	90	120	86	72
Pulse Width (ns)	300	600	300	300
Delay (ns)	1800	1800	2000	1800
Gate Spacing (ns)	300	600	300	300
Number of Coherent Avgs.	6	6	6	4
Number of Spectral Avgs.	16	21	24	37
FFT Length	64	64	64	64
Number of Coded Bits	32	32	8	not coded
Number of Gates	218	150	240	218
Duty Cycle (%)	10.7	16.0	2.8	0.4
Dwell Time (s)	0.6	1.0	0.8	0.7
Observation Time (s)	9	9	8	9
Min. Detectable Signal (dBm)	-129	-133	-130	-132
Range Resolution (m)	45	90	45	45
Height Coverage (km)	0.3-10.1	0.3-13.8	0.1-11.1	0.3-10.1
Unambiguous Velocity (m/s)	±4.0	±3.0	*4. 2	±7.5
Velocity Resolution (m/s)	0.13	0.09	0.13	0.23
Unambiguous Range (km)	13.5	18.0	12.9	10.8
Estm. Sensitivity (dBZ at 5) km)	-44	-50	-39	-32

be transported more easily, either separately or as part of a smaller container. A block diagram of the radar design is shown in Fig. 2, and we list in Table 1 typical operating characteristics of the radar.

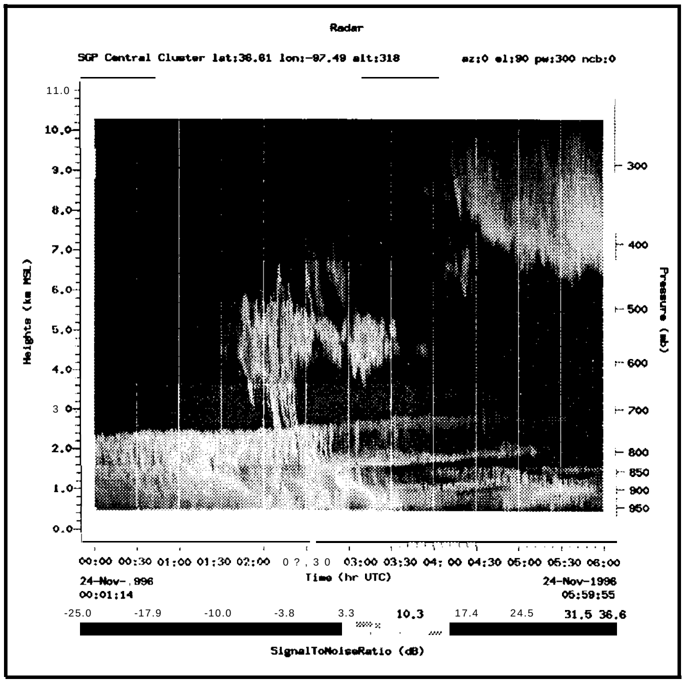

Fig. 3. A time-height display of signal-to-noise ratio for mode 3 in Table 1 (uncoded) at the Southern Great Plains (SGP) CART site near Lament, Oklahoma, for a 6-hour period on November 24, 1996. Range resolution is 45 m, dwell time is 9 s.

Up to four different modes of operation can be locally or remotely established, through which the radar routinely cycles. Maximum sensitivity for the modes postulated here is -38 dBZ at 20 km altitude, which compares favorably with NOAA's much more sophisticated and expensive scanning research radar, NOAA/K [Kropfli et al., 1990, Kropfli and Kelly, 1996]. Cycling automatically and rapidly through modes of varying sensitivity permits one to better accommodate the huge dynamic range in atmospheric reflectivities experienced in practice, from low-level precipitation to cirrus at high-altitude. Time and height resolutions are on the order of 10 s and 50 m, although within reason these can be adjusted for the needed application. Fig. 3 is a typical time-height display of the radar signal-to-noise ratio (zeroth spectral moment) in a situation where several layers and types of clouds are present. The radar is a full Doppler system, hence it calculates and can store complete spectra for each range gate, but typically it only retains the first three spectral moments calculated from the spectra, in an effort to reduce the quantity of data. The Doppler capability permits one to easily discern the melting layer in cold, precipitating clouds, because at that height the precipitation fall speed increases abruptly as the snow/graupel condenses to liquid droplets and accelerates. Doppler capability is especially important when combining the radar measurements with other instruments, such as radiometers and lidars [Matrosov et al., 1994, Intrieri et al., 1995], to measure important microphysical parameters of the clouds, such as vertical profiles of effective particle radius, ice mass content, etc. These combined techniques potentially permit one to automatically detect those portions of clouds where icing conditions exist, an important piece of knowledge for aircraft controllers.

Range Sidelobes

The radar achieves its relatively high average power output (25 w) from the low peak power (100 w) TWTA by employing pulse compression techniques, i.e. by transmitting long pulses (up to 20 μs) that are internally phase-coded, typically in 0.6 μs segments. Standard techniques [Schmidt et al., 1979] used to receive and decode such pulses permit us to retain the range resolution associated with the phase-coded segments (90 m), but at the expense of generating weak, artificial returns at ranges other than the true range. Since these artificial signals are typically 25-35 dB below the true returns, and occur at ranges bounded by the length of the code used, they are easy to identify in most situations. However, they can be a problem when strong gradients in reflectivity and/or large Doppler velocities are present. By automatically cycling through several modes of radar sensitivity, from no pulse compression to maximum compression, we find it is possible for an experienced analyst to unambiguously understand the true layering of clouds. However, we are working to incorporate improved coding and processing techniques to further reduce the level of range sidelobe artifacts, since they are clearly an unwanted distraction.

Plans

We are planning to deploy one additional radar every six months in the next two years to ARM's other CART sites, e.g. to the north slope of Alaska and Manus Island, Papua New Guinea. At such locations, the radars will need to run in a truly unattended mode, since only relatively inexperienced local personnel will be available to monitor the radar's operation. In addition, ETL expects to deploy a similar cloud radar for 12-16 months on the ice pack north of Alaska as part of the Office of Naval Research (ONR) and National Science Foundation (NSF) joint Surface HEat Budget of the Arctic Ocean (SHEBA) campaign, beginning in late 1997.

While ETL develops and deploys the radars for DOE, it is also working to establish a Cooperative Research and Development Agreement (CRADA) with industry to transfer the technology to the private sector, because it is not in a research laboratory's mission to market technology to users, or to support it over many years. A CRADA will make the technology more robust and keep it abreast of the latest improvements, make it commercially available, and help ensure long-term, professional support. We expect the CRADA to be signed in early 1997 and for a commercial version of the 35-GHz cloud-profiling Doppler radar to be available within one year. At that time, or sooner, we hope supervisors of both military and civilian air traffic control facilities will seriously consider the benefits of having available to controllers, both on land and at sea, detailed knowledge of local cloud layering, turbulence, and icing conditions provided by these inexpensive ($500K), compact radars.

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